Physicochemical and Organoleptic Characteristics of Non-Gluten Noodles from Composite Flour and Rucah Fish Meal

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Abstract. The rising prevalence of gluten-related disorders has increased the demand for gluten-free products. Traditional noodles, primarily made from wheat flour, are unsuitable for individuals with gluten intolerance, necessitating alternative formulations. This study aims to develop gluten-free noodles using composite flours: Mocaf, arrowroot starch, cornstarch, and fish meal, and to evaluate their physicochemical and sensory properties. The research utilized a Completely Randomized Design (CRD) with seven different formulations, varying in the proportions of these ingredients. The noodles were analyzed for moisture, ash, protein, fat, and carbohydrate content using standard methods. Sensory evaluation was conducted by a panel of 30 trained assessors using a hedonic scale. The results indicated that the proportions of Mocaf, arrowroot starch, cornstarch, and fish meal significantly affected the noodles' moisture, ash, fat content, and sensory attributes like flavor, color, and overall preference. The most preferred formulation was the control (F0), consisting of 100% wheat flour, due to its familiar taste and appearance. In contrast, formulations with higher fish meal content were lfess favored due to a strong fishy odor and darker color. In conclusion, while the addition of fish meal enhances the nutritional profile, it negatively impacts the sensory qualities of gluten-free noodles.

1 Introduction

The increasing prevalence of gluten-related disorders, such as Celiac Disease and non-celiac gluten sensitivity, has driven a significant demand for gluten-free products globally. Celiac Disease is an autoimmune disorder triggered by ingesting gluten, a protein found in wheat, barley, and rye, which damages the small intestine and impairs nutrient absorption. Non-celiac gluten sensitivity, while less severe, still requires a strict gluten-free diet to manage symptoms. This growing health concern has led to an urgent need for alternative food products that are both gluten-free and nutritionally adequate (1).

Traditional noodles are primarily made from wheat flour, which contains gluten, making them unsuitable for individuals with these conditions. In response, considerable research has been conducted into developing gluten-free noodles using alternative flours. Modified

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Cassava Flour (Mocaf) has emerged as a promising substitute due to its high starch content and beneficial properties, such as improved viscosity, gel-forming ability, and reduced glycemic index (2). Mocaf is produced through a fermentation process that enhances the flour's functional characteristics, making it an ideal candidate for gluten-free food production (3).

Arrowroot starch is another viable alternative for gluten-free noodles. Derived from the tubers of the Maranta arundinacea plant, arrowroot starch is known for its high digestibility, thickening properties, and ability to improve the texture and stability of food products (4). Additionally, cornstarch, with its high amylopectin content, is often used in gluten-free formulations to provide structural stability and enhance the texture of the final product (5).

Incorporating protein into gluten-free noodles is crucial to improving their nutritional profile. Fish meal, a by-product of the fishing industry, offers a rich source of protein, including essential amino acids such as lysine and leucine. It also contains omega-3 fatty acids, which are beneficial for cardiovascular health and have anti-inflammatory properties (6). However, the combination of these alternative flours and protein sources in gluten-free noodles has not been extensively studied, particularly in optimizing their physicochemical and sensory properties.

Previous studies have explored the use of various flours in gluten-free noodle production. For example, research by (6) focused on gluten-free dry noodles made from sorghum and Mocaf, highlighting the importance of flour ratio and drying temperature in determining the chemical and organoleptic qualities of the noodles. Additionally, a study by (5) examined the utilization of canna flour in gluten-free food products, emphasizing the potential of local tubers as sustainable alternatives to wheat flour.

The novelty of this study lies in the unique combination of Mocaf, arrowroot starch, and cornstarch, supplemented with fish meal, to produce gluten-free noodles with enhanced nutritional and sensory properties. While individual components like Mocaf and fish meal have been studied separately, their synergistic effects in a gluten-free noodle formulation remain underexplored. This research aims to fill this gap by investigating how different proportions of these ingredients affect the noodles' physicochemical properties, such as moisture content, ash content, protein content, fat content, and carbohydrate content, as well as their sensory attributes like taste, texture, and appearance.

This study's findings could significantly contribute to the development of gluten-free products that cater to the dietary needs of individuals with gluten intolerance and provide enhanced nutritional benefits. By utilizing local resources like Mocaf and arrowroot starch, this research supports food diversification and sustainability, aligning with broader efforts to reduce dependency on imported wheat flour and promote the use of indigenous crops. In summary, this study aims to optimize the formulation of gluten-free noodles using a combination of Mocaf, arrowroot starch, cornstarch, and fish meal. The research will evaluate the impact of these ingredients on the noodles' physicochemical and sensory properties, aiming to identify the most effective formulation for producing high-quality, nutritionally enriched gluten-free noodles. The novelty of this approach lies in integrating multiple alternative ingredients to achieve a balanced product that meets health and sensory expectations.

2. Materials and Methods

2.1 Materials

The primary materials used in this study include Mocaf (Modified Cassava Flour), arrowroot starch, cornstarch, and fish meal. Mocaf was obtained from a local supplier and produced through a fermentation process involving lactic acid bacteria to enhance its functional properties, such as viscosity and gel-forming ability (6). Arrowroot starch was sourced from the tubers of *Maranta arundinacea*, known for its high purity and thickening properties, while cornstarch, rich in amylopectin, was procured from a commercial supplier. Fish meal, used to enrich the protein content of the noodles, was obtained from a local fish processing plant.

2.2 Research Design

This study employed a Completely Randomized Design (CRD) with seven different formulations, each repeated three times to ensure the reliability of the results. The formulations varied in the proportions of Mocaf, arrowroot starch, and cornstarch, combined with fish meal to explore their effects on the physicochemical and sensory properties of gluten-free noodles.

The formulations tested were as follows:

- **F0 (Control):** 100% wheat flour (traditional noodles)
- **F1:** 20% Mocaf, 50% arrowroot starch, 30% cornstarch, 5% fish meal
- **F2:** 20% Mocaf, 60% arrowroot starch, 20% cornstarch, 5% fish meal
- **F3:** 30% Mocaf, 50% arrowroot starch, 20% cornstarch, 5% fish meal
- **F4:** 20% Mocaf, 50% arrowroot starch, 30% cornstarch, 10% fish meal
- **F5:** 20% Mocaf, 60% arrowroot starch, 20% cornstarch, 10% fish meal
- **F6:** 30% Mocaf, 50% arrowroot starch, 20% cornstarch, 10% fish meal

2.3 Noodle Preparation

The noodles were prepared following a standardized method. The dry ingredients (Mocaf, arrowroot starch, cornstarch, and fish meal) were weighed according to the formulations and thoroughly mixed. Water was gradually added to the mixture while kneading until a homogeneous dough was formed. The dough was then rolled out and cut into thin strips to form noodles. The noodles were dried at a controlled temperature of 60°C for 24 hours to reduce moisture content and ensure shelf stability (5).

2.4 Physicochemical Analysis

The physicochemical properties of the noodles, including moisture content, ash content, protein content, fat content, and carbohydrate content, were analyzed using standard methods. Moisture and ash contents were determined by gravimetric methods, while protein content was analyzed using the Kjeldahl method (7). Fat content was measured through Soxhlet extraction, and carbohydrate content was calculated by difference, subtracting the sum of moisture, ash, protein, and fat from the total (7).

2.5 Sensory Evaluation

Sensory evaluation was conducted to assess the organoleptic properties of the noodles, including taste, texture, appearance, and overall acceptability. A panel of 30 trained assessors evaluated the noodles using a hedonic scale ranging from 1 (dislike extremely) to 7 (like extremely). The evaluations were performed under controlled conditions to minimize variability (8).

2.6 Data Analysis

Data obtained from physicochemical and sensory evaluations were analyzed using Analysis of Variance (ANOVA). Significant differences between treatments were further analyzed using the Least Significant Difference (LSD) test at a 5% significance level. The results were interpreted to identify the optimal formulation for gluten-free noodles with desirable physicochemical and sensory properties.

3. Result and Discussion

3.1 Protein Content

The analysis of variance indicated that the proportions of Mocaf flour, arrowroot starch, cornstarch, and fish meal significantly affect the protein content of the gluten-free noodles (P>0.05). The average protein content of the gluten-free noodles produced in this study ranged from 1.30% to 6.08% (Table 1), which falls below the Indonesian National Standard (SNI 01-2774-1992) requirements for dry noodles, which stipulate a minimum of 8% for quality I and 11% for quality II.

The lower protein content observed in the gluten-free noodles can be attributed primarily to the low protein content of the composite flours used in the formulation. Mocaf flour, which is a significant component, contains only about 1.2% protein (6). Similarly, arrowroot starch and cornstarch have very low protein contents, at approximately 1.03% and 0.35%, respectively (3). Although fish meal is a high-protein ingredient with protein levels ranging from 51% to 58% (5), the limited quantity added to the formulation was insufficient to elevate the protein content to meet the standard requirements.

Table 1. Chemical composition of non-gluten noodles

Treatment	Protein content (%)	Water content (%)	Ask content (%)	Fat content (%)	Carbohydrate content (%)
F0	6.05a	8.03^{c}	1.71^{a}	10.42a	73.80c
F1	4.08b	9.09^{d}	1.84^{a}	12.77b	71.59d
F2	2.92c	5.66^{b}	2.47^{ab}	10.25a	78.26a
F3	1.30d	6.06^{a}	2.91^{abc}	11.59ab	79.21a
F4	3.15c	4.66^{a}	3.60^{bc}	11.30ab	76.78b
F5	3.78b	5.35^{ab}	4.09^{c}	8.85c	77.26b
F6	3.68b	5.10^{ab}	4.12^{c}	9.82a	77.78b

Note: Numbers followed by different lowercase letters indicate significant differences based on the DMRT test (α=5%)

Furthermore, the protein content of the noodles is influenced by the composition of the composite flours. The use of flours with inherently low protein levels, such as Mocaf and cornstarch, significantly reduces the overall protein content of the final product (6). This is supported by (9), who noted that the protein content of the raw materials directly impacts the protein levels in the finished product.

While the addition of fish meal did enhance the protein content to some extent, the increase was not enough to meet the SNI standards. Research by (10) found that increasing the concentration of fish meal proportionally raises the protein content in noodles; however, excessive addition can negatively affect the sensory characteristics and texture of the noodles (11).

To achieve protein content that meets SNI standards, it may be necessary to increase the proportion of fish meal in the formulation or to incorporate other high-protein sources. Additionally, the development of products using local ingredients like Mocaf flour should consider alternative strategies to boost protein content, such as adding protein isolates or utilizing processing techniques that enhance protein bioavailability (3).

Trash fish are small-sized fish often considered low economic value, yet they possess significant potential as a protein source. Based on the chart (Figure 1), glutamic and aspartic acids are the most abundant amino acids, comprising around 15% and 12% of the total amino acids, respectively. Glutamic acid is crucial in imparting umami flavor to food products, making rucah fish meal a potential ingredient for flavor enhancement in food processing (12). Additionally, essential amino acids like lysine and leucine also show significant content, each around 7-8%. Lysine is vital for growth and tissue repair, while leucine is involved in protein synthesis and energy metabolism (13).

This rich protein content indicates that trash fish have great potential as an alternative protein source for both human consumption and animal feed. Optimizing the utilization of trash fish through further processing can help reduce fishery resource waste and increase economic value (14).

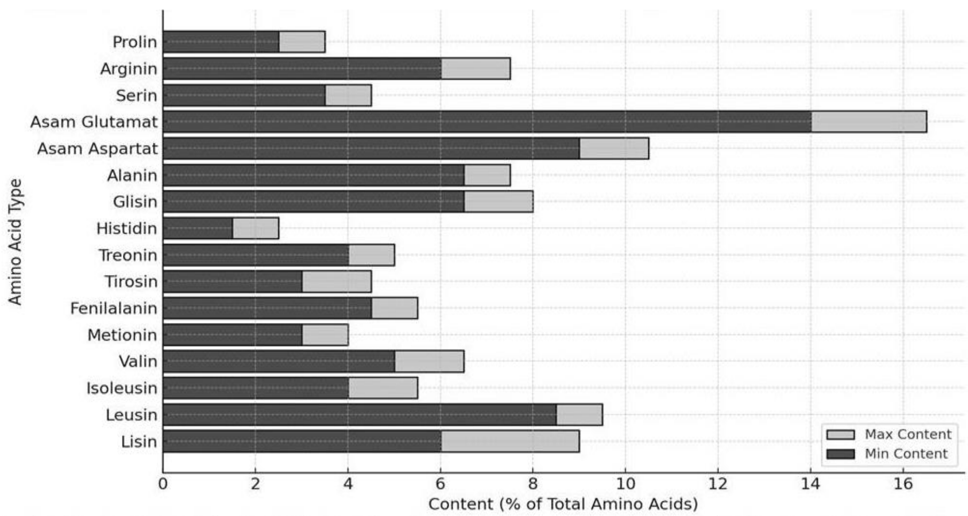

Figure 1. Amino acid composition of trash fish

3.2 Moisture Content

The analysis of variance indicated that the proportions of Mocaf flour, arrowroot starch, cornstarch, and fish meal significantly influenced the moisture content of gluten-free noodles (P<0.05). Post-hoc analysis using the DMRT method at the 5% significance level revealed a trend of decreasing moisture content in gluten-free noodles as the composition of the ingredients varied. The average moisture content ranged from 4.66% to 9.09%, which complies with the Indonesian National Standard (SNI 01-2774-1992) for dry noodles, stipulating a maximum moisture content of 8% for quality I and 10% for quality II.

(12) noted that the moisture content of noodles is closely related to their gluten content, as gluten plays a crucial role in retaining water during the drying process. In gluten-free noodles, the amylose content of the raw materials becomes a significant factor influencing moisture levels. Amylose has a lower water-binding capacity than amylopectin, leading to greater water release during drying, especially in noodles with higher amylose content (15). In this study, the varying amylose content of the different flours used—19% amylose and 81% amylopectin in Mocaf (16), 24.64% amylose and 76.46% amylopectin in arrowroot starch (17), and 20-30% amylose and 70-80% amylopectin in cornstarch (18)—helps explain the observed differences in moisture content.

The addition of fish meal also contributed to the reduction in moisture content. The heating process during noodle production causes protein denaturation in fish meal, rendering the protein more hydrophobic. This hydrophobic nature hinders water absorption by the starch granules, resulting in a longer gelatinization time and lower final moisture content (19).

These findings are consistent with previous studies that reported lower moisture content in gluten-free noodles made from Mocaf and arrowroot starch (20), (21). Overall, the moisture content of the gluten-free noodles produced in this study meets the expected quality standards for dry noodles, ensuring product stability and shelf life.

3.3 Ash Content

The analysis of variance revealed that the proportions of Mocaf flour, arrowroot starch, cornstarch, and fish meal significantly impacted the ash content of the gluten-free noodles ($P<0.05$). Post-hoc analysis using the DMRT method at the 5% significance level indicated a general trend of increasing ash content in the gluten-free noodles, depending on the composition of the ingredients used. The ash content of the noodles ranged from 1.71% to 4.12%, which is consistent with the range reported in previous studies on gluten-free noodles (22).

Ash content is an indicator of the total mineral content in food, and it is directly influenced by the inorganic components of the raw materials used in the noodle formulation. Mocaf flour, for example, has an ash content of approximately 1.5% (23), arrowroot starch contains about 0.34% ash (17), and cornstarch has an ash content of 0.15% (23). In contrast, fish meal, which is known for its high mineral content, has an ash content of approximately 27.89% (24). The higher ash content observed in the gluten-free noodles can be attributed to the addition of fish meal, which significantly increases the mineral content of the final product (3).

The findings are consistent with the results of other studies, which have shown that increasing the proportion of ingredients with higher ash content, such as Mocaf or fish meal, leads to a corresponding increase in the ash content of the final product. For example, research by (20) demonstrated that higher Mocaf flour usage resulted in increased ash content in gluten-free noodles. Similarly, (25) reported that increasing the concentration of cornstarch also contributed to higher ash content.

However, it is important to note that while higher ash content indicates a richer mineral profile, it may also exceed the acceptable limits for certain food products. According to the Indonesian National Standard (SNI 01-2774-1992), the maximum allowable ash content for dry noodles is 3%. In this study, formulations F5 and F6 slightly exceeded this threshold, with ash contents of 4.09% and 4.12%, respectively. These results suggest that while the addition of fish meal enhances the nutritional value of the noodles, careful consideration must be given to balancing the ash content to ensure compliance with quality standards.

3.4 Fat Content

The analysis of variance revealed that the proportions of Mocaf flour, arrowroot starch, cornstarch, and fish meal did not significantly affect the fat content of the gluten-free noodles (P>0.05). The average fat content of the gluten-free noodles, as influenced by the various proportions of these ingredients, ranged from 8.85% to 12.77%. This range is notably higher than the fat content typically reported in similar studies, such as those by (26), which found fat content in non-wheat noodles with added fish meal to be between 0.85% and 1.07%. The difference in fat content can be attributed to the variation in the type and composition of the flours and fish meal used (2), (6).

The fat content in dry noodles is influenced by several factors, including the natural fat present in the ingredients and the interaction between these components during processing. Fish meal, which is rich in natural fat, significantly contributes to the overall fat content. The type of fish used in the fish meal can also play a role; larger or older fish generally have higher fat content, as noted by (27). Additionally, the grinding process during fish meal production can enhance fat release by increasing the surface area exposed to heat, thereby promoting the breakdown of fat-containing cells (28).

The denaturation of proteins during the noodle-making process also influences fat content. Protein denaturation can lead to a reduction in the water-binding capacity and emulsification properties of the proteins, which may result in the loss of fat during cooking and drying processes (29). Furthermore, the heating involved in noodle production can cause the coagulation of proteins, making it easier for water and fat to be released from the noodles (2,30).

The results of this study show that the fat content range of 8.85% to 12.77% is higher than expected for gluten-free noodles. This discrepancy might be due to the specific characteristics of the fish meal used in this study, which had a higher fat content compared to the fish meal used in previous research, such as that from motan fish, which contains about 7.80% fat (26). In contrast, the fish meal derived from "ikan rucah" used in this study has a fat content of 11.26% (31), which likely contributed to the higher overall fat content observed in the noodles.

3.5 Carbohydrate Content

The analysis of variance indicated that the proportions of Mocaf flour, arrowroot starch, cornstarch, and fish meal did not significantly affect the carbohydrate content of the gluten-free noodles (P>0.05). The average carbohydrate content observed in the noodles ranged from 71.59% to 79.21%, which is consistent with previous studies, such as those by (15), where carbohydrate content in dry noodles with Mocaf flour substitution ranged from 69.01% to 81.65%.

The high carbohydrate content in these gluten-free noodles can be primarily attributed to the carbohydrate-rich nature of the flour used. Mocaf flour, arrowroot starch, and cornstarch are all known for their high carbohydrate content, which significantly contributes to the overall carbohydrate levels in the noodles. For instance, Mocaf flour contains approximately 89.38% carbohydrates (32), arrowroot starch contains about 90.29% carbohydrates (17), and cornstarch has about 73.15% carbohydrates (33). These high levels of carbohydrates are essential in forming the bulk of the noodle structure and providing the necessary energy content in the final product (5).

Moreover, carbohydrate content calculated by the difference method considers the subtraction of the sum of the other macronutrients (protein, fat, ash) and moisture content from the total weight. (34) emphasized that this method reveals a higher carbohydrate content when other nutritional components are lower, which explains the relatively high carbohydrate levels observed in these noodles.

The balance between different ingredients, such as the combination of high-carbohydrate flours with lower-fat content fish meal, resulted in a final product that meets the expected carbohydrate standards for gluten-free noodles. Studies by (3) have shown that the carbohydrate content plays a crucial role in determining the cooking and textural qualities of gluten-free noodles, influencing properties like cooking time and texture.

In conclusion, the carbohydrate content in these gluten-free noodles is primarily driven by the inherent properties of the flour used. The findings underscore the importance of ingredient selection in achieving the desired nutritional profile for gluten-free products, ensuring that they are both nutritionally adequate and texturally acceptable (5).

4. Organoleptic Test

4.1 Flavor

The analysis of variance indicated that the proportions of Mocaf flour, arrowroot starch, cornstarch, and fish meal significantly affected the flavor of the gluten-free noodles ($P<0,05$). As seen in Table 16, the flavor scores tended to decrease with higher proportions of these ingredients. The average flavor scores for the gluten-free noodles ranged from 2.40 to 4.56, indicating that the fish flavor became more pronounced as more fish meal was added. This is consistent with the findings of (3), who noted that the incorporation of strong-flavored ingredients, such as certain types of starches and proteins, can significantly alter the sensory profile of gluten-free noodles.

Table 2. Organoleptic test results of non-gluten noodles from a mixture of composite flour and fish flour

Treatment	**Flavor**	**Colour**	**Aroma**	**Preference**
F0	4.56^{d}	4.80^{c}	4.80^{c}	4.76^{c}
F1	4.00^{c}	3.52^{b}	3.64^{b}	3.60^{b}
F2	3.48^{b}	3.40^{b}	3.56^{b}	3.40^{b}
F3	3.60^{b}	3.32^{b}	3.60^{b}	3.56^{b}
F4	2.60^{a}	2.72^{a}	2.64^{a}	2.60^{a}
F5	2.48^{a}	2.48^{a}	2.44^{a}	2.56^{a}
F6	2.40^{a}	2.44^{a}	2.40^{a}	2.64^{a}

Note: Numbers followed by different lowercase letters indicate significant differences based on the DMRT test (α=5%)

The distinct fish flavor in these noodles is likely due to the high protein and fat content in the fish meal, which includes glutamic acid—a compound known for enhancing savory (umami) taste (35). Additionally, the fat content in fish meal contributes to the richness and depth of flavor, making the fish taste more dominant. This is supported by research from (6), which found that ingredients with high protein content, such as fish meal, can intensify the umami taste in food products.

Furthermore, the carbohydrate composition of the flours used, such as those in Mocaf and arrowroot, also plays a role in the flavor profile. The presence of glucose, sucrose, and starch can subtly influence sweetness and overall flavor perception, as noted by (36). However, when combined with the strong flavor of fish meal, these sweet notes might be overshadowed, leading to a lower overall flavor score. This trend of decreasing flavor scores with increased fish meal content aligns with findings from (2), who observed similar effects in gluten-free noodles made with various starches.

4.2 Color

The analysis of variance revealed that the proportions of Mocaf flour, arrowroot starch, cornstarch, and fish meal significantly affected the color of the gluten-free noodles ($P<0.05$). The average color scores, as shown in Table 17, decreased with increasing proportions of these ingredients, with scores ranging from 2.44 to 4.80. This decrease in color score suggests a shift towards a more grayish hue in the noodles, primarily due to the inherent color of the raw materials used. The darker color observed in the noodles can also be attributed to the Maillard reaction, a non-enzymatic browning process that occurs during heating. This reaction involves the interaction between carbohydrates and amino acids, particularly those found in fish meal, resulting in the formation of melanoidins, which impart a brownish tint to the noodles (22).

The findings of this study are consistent with previous research by (22), who noted that the use of various flours in gluten-free noodle formulations can significantly impact the final color of the product. In particular, ingredients with higher protein and fat contents, such as fish meal, tend to promote darker coloration due to the increased potential for Maillard browning during cooking and drying.

Additionally, the type of flour used plays a crucial role in determining the color. Mocaf flour, for example, tends to produce a lighter color, while arrowroot starch and cornstarch can contribute to a more neutral or slightly yellowish hue. However, the addition of fish meal overrides these effects, leading to the observed grayish tones. This aligns with the findings of (6), who also reported that the choice of ingredients, particularly those prone to browning reactions, is critical in controlling the color of gluten-free noodles.

4.3 Aroma

The analysis of variance indicated that the proportions of Mocaf flour, arrowroot starch, cornstarch, and fish meal significantly influenced the aroma of the gluten-free noodles ($P<0.05$). As observed in Table 18, the aroma scores decreased with the increasing proportion of these ingredients, particularly fish meal, resulting in an intensified fishy odor in the noodles. The average aroma scores ranged from 2.40 to 4.80, reflecting a strong fishy smell, which is commonly associated with fish meal. This is primarily due to the presence of trimethylamine oxide (TMAO) in fish, which, when broken down, releases trimethylamine (TMA), a compound responsible for the fishy odor (35).

The oxidation of unsaturated fatty acids in fish meal also contributes to rancidity, further affecting the aroma negatively. This process leads to the formation of off-flavors, particularly in products stored over time or exposed to heat during processing (37). The use of Mocaf, arrowroot, and cornstarch, while beneficial for texture and structural properties, does little to mask the strong odor imparted by fish meal.

Interestingly, research by (22) has shown that the combination of different flours can influence the aroma of gluten-free noodles, depending on the blend's ability to either enhance or suppress specific sensory attributes. For example, the natural aroma of maize or rice flour may help mitigate undesirable odors to some extent (22). In summary, while the incorporation of fish meal into gluten-free noodles can improve nutritional content, it also significantly impacts aroma, often in an undesirable way. Future formulations might consider the use of natural flavor enhancers or masking agents, such as those suggested by (5), to reduce the fishy odor and improve overall consumer acceptance.

5 Preference

The analysis of variance revealed that the proportions of Mocaf flour, arrowroot starch, cornstarch, and fish meal significantly influenced the overall preference scores for the gluten-free noodles ($P<0.05$). As shown in Table 19, the preference scores decreased with higher proportions of fish meal, particularly in formulations like F5, where the combination of Mocaf flour (20%), arrowroot starch (60%), cornstarch (20%), and fish meal (10%) resulted in the lowest preference scores, ranging from 2.64 to 4.76. Panelists generally preferred the F0 formulation, which consisted entirely of wheat flour, due to its more familiar taste, color, and lack of fishy odor.

The lower preference for formulations containing higher amounts of fish meal can be attributed to the distinct fishy aroma and grayish color that these noodles exhibited. These sensory attributes are less desirable in noodle products, as highlighted by (38), who found that sensory properties such as aroma and color play a critical role in consumer acceptance of gluten-free noodles. The strong fish flavor, combined with the darker color due to the Maillard reaction and oxidation processes, negatively impacted the panelists' overall liking.

Moreover, previous studies, such as (39), also noted that gluten-free noodles with unconventional ingredients might have lower acceptance levels due to their unfamiliar sensory characteristics. To enhance the appeal of gluten-free noodles, future formulations could benefit from optimizing ingredient ratios and incorporating flavor enhancers or masking agents to improve the sensory qualities of the product.

6 Conclusion

This study successfully developed gluten-free noodles using composite flours, including Mocaf, arrowroot starch, cornstarch, and fish meal. The research demonstrated that the proportions of these ingredients significantly influenced the physicochemical and sensory properties of the noodles. While the inclusion of fish meal enhanced the protein and mineral content, it also led to a stronger fishy odor and darker color, which negatively impacted the overall preference scores. The most preferred formulation was the control (F0) made entirely of wheat flour, indicating that gluten-free alternatives still face challenges in matching the sensory qualities of traditional wheat-based noodles. However, the study highlights the potential of using local ingredients such as Mocaf and arrowroot starch in gluten-free products, promoting food diversification and sustainability. To improve the sensory acceptance of gluten-free noodles, future research should explore the use of natural flavor enhancers or masking agents, as well as optimizing ingredient ratios to balance nutritional benefits with desirable sensory attributes. This approach could lead to the development of high-quality gluten-free products that meet both health and consumer expectations.

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References

1. B. Aljada, A. Zohni, and W. El-Matary. The gluten-free diet for celiac disease and beyond. *Nutrients*. **13** 11 2021. Doi: 10.3390/nu13113993.
2. U. Purwandari, A. Khoiri, M. Muchlis, B. Noriandita, N. F. Zeni, N. Lisdayana, and E. Fauziyah. Textural, cooking quality, and sensory evaluation of gluten-free noodle made from breadfruit, konjac, or pumpkin flour. *Int Food Res J*. **21** 4. 2014.
3. S. Sutheeves, P. Chai-Uea, and D. Thirathumthavorn. Impact of hydrocolloids on the physico-chemical and sensory properties of gluten-free instant noodles from rice flour and mung bean starch. *Ital J Food Sci*. **32** 2 2020. Doi: https://doi.org/10.14674/IJFS-1551.
4. D. Damat, R. H. Setyobudi, J. S. Utomo, A. Vincēviča-Gaile, A. Tain, and D. D. Siskawardani. The Characteristics and Predicted of Glycemic Index of Rice Analogue from Modified Arrowroot Starch (Maranta arundinaceae L.). *Jordan J Biol Sci*. **14** 3 2021. Doi: https://doi.org/10.54319/jjbs/140302.
5. D. Histifarina, A. Rahman, N. Purnamasari, and R. Rahmat. Utilization of canna (Canna edulis ker.) as raw material for non-gluten processed food to supporting food diversification program: a review. *IOP Conf Ser Earth Environ Sci*. **12** 46 2023. Doi: 10.1088/1755-1315/1246/1/012045.
6. N. F. Rizky N. A. N. F. Kurnia Hartati, and N. Hariyani. Chemical and Organoleptic Quality of Free-Gluten Dry Noodles from Sorghum (Sorghum bicolor) and Modified Cassava Flour with Different Drying Temperature. *SAGA J Technol Inf Syst.* **1** 3 2023. Doi: https://doi.org/10.58905/saga.v1i3.69.
7. AOAC, Official Methods of Analysis. 16th Ed, (Gaithersburg, MD: AOAC International, 1995).
8. ISO, Sensory Analysis - Methodology - General guidance. ISO 6658. 2005. 20 p.
9. S. Fillaili, F. W. Ningtyias, dan S. Sulistiyani. Pengaruh Penambahan Tepung Ampas Tahu Terhadap Kadar Protein, Kadar Serat, Kadar Air Dan Daya Terima Bakso Ikan Nila (Oreochromis Niloticus). *Bul Penelit Sist Kesehat*. **23** 4 2020.
10. C. Litaay, A. Indriati, Sriharti, N. K. I. Mayasti, R. I. Tribowo, Y. Andriana Y, and R. C. E. Andriansyah. Physical, chemical, and sensory quality of noodles fortification with anchovy (Stolephorus sp.) flour. *Food Sci Technol*. **42** 2022. Doi: https://doi.org/10.1590/fst.75421.
11. W. Y. Koh, P. Matanjun, X. X. Lim, and R. Kobun. Sensory, Physicochemical, and Cooking Qualities of Instant Noodles Incorporated with Red Seaweed (Eucheuma denticulatum). *Foods*. **11** 17 2022. Doi: https://doi.org/10.3390/foods11172669.
12. M. Wang, M. Liang, J. Ge, X. Ma, S. Su, J. Li, F. Yu, H. Li, C. Song, N. Wu, P. Xu, Y. Tang, and G. Xu. Transcriptome Analysis of Hepatopancreas Provides Insights into Differential Metabolic Mechanisms of Eriocheir sinensis Feeding on Trash Fish and Formulated Feed. *Front Biosci - Landmark*. **27** 8 2022. Doi: 10.31083/j.fbl2708226.
13. D. E. Matthews. Review of lysine metabolism with a focus on humans. *Journal of Nutrition.* **150** 2020. Doi: 10.1093/jn/nxaa224.
14. I. Tugiyono, G. Febryano, Y. Puja, and Suharso. Utilization of fish waste as fish feed material as an alternative effort to reduce and use waste. *Pakistan J Biol Sci*. **23** 5 2020. Doi: I. Tugiyono, G. Febryano, Y. Puja, and Suharso. Utilization of fish waste as fish feed material as an alternative effort to reduce and use waste. *Pakistan J Biol Sci*. **23** 5 2020. Doi: 10.3923/pjbs.2020.701.707.
15. S. B. Wahjuningsih, D. Anggraeni, Z. D. Siqhny, A. Triputranto, D. Elianarni, L. Purwitasari, and M. N. Azkia. Formulation, Nutritional and Sensory Evaluation of Mocaf (Modified Cassava Flour) Noodles with Latoh (Caulerpa lentillifera) Addition. Curr Res Nutr Food Sci. **11** 3 2023. Doi: https://dx.doi.org/10.12944/CRNFSJ.11.3.08.

16. F. Violalita, Evawati, S. Syahrul, H. F. Yanti, and K. Fahmy. Characteristics of Gluten-Free Wet Noodles Substituted with Soy Flour. In: *IOP Conference Series: Earth and Environmental Science*. **515** 2020. Doi: 10.1088/1755-1315/515/1/012047.
17. D. N. Faridah, D. Fardiaz, N. Andarwulan, dan T. C. Sunarti. Karakteristik sifat fisikokimia pati garut (Maranta arundinaceae). *Agritech*. **34** 1 2014. Doi: https://doi.org/10.22146/agritech.9517.
18. A. Palanisamy, G. Moulin, M. Ramaioli, A. Plana-Fattori, D. Flick, and P. Menut. Determination of the mechanical properties of gelatinized starch granule from bulk suspension characterization. *Rheol Acta*. **61** 4-5 2022. Doi: 10.1007/s00397-022-01325-4.
19. H. T. Nguyen, G. S. Hilmarsdóttir, T. Tómasson, S. Arason, and M. Gudjónsdóttir. Changes in Protein and Non-Protein Nitrogen Compounds during Fishmeal Processing—Identification of Unoptimized Processing Steps. *Processes*. **10** 4 2022. Doi: https://doi.org/10.3390/pr10040621.
20. H. Herawati, and E. Kamsiati. Characteristics of various flour and gluten free noodles from Indonesian local food. *In: IOP Conference Series: Earth and Environmental Science.* **803** 2021. Doi: 10.1088/1755-1315/803/1/012036.
21. A. B. Puspitasari, G. J. Manuhara, D. L. N. Fibri, and D. R. A. Muhammad. Evaluating Arrowroot Starch Modification and Application in Wet Noodles. *J Exp Life Sci.* **12** 1 2022. Doi: https://doi.org/10.21776/ub.jels.2022.012.01.01.
22. N. Bilgiçli. Some chemical and sensory properties of gluten-free noodle prepared with different legume, pseudocereal and cereal flour blends. J Food Nutr Res. **52** 4 2013.
23. SNI. SNI 8217:2015: Standard for Dry Noodles. Indonesia: Badan Standardisasi Nasional (BSN) (2015).
24. S. Janbakhsh, S. S. P. Hosseini, M. M. Shamsaie. Nutritional value and heavy metal content of fishmeal from the Southwest Caspian Sea. *Casp J Environ Sci*. **16** 4 2018. Doi: 10.22124/CJES.2018.3200.
25. A. Ghada. and S. A. M. Alfauomy. Utilization of Yellow Corn in Preparing High Nutritional Value Gluten-Free Noodles. *Suez Canal Univ J Food Sci*. **7** 1 2020. Doi: 10.21608/scuj.2020.178513.
26. R. Irsalina, and S. D. Lestari, H. Herpandi. Karakteristik Fisiko-Kimia dan Sensori Mie Kering dengan Penambahan Tepung Ikan Motan (Thynnichthys thynnoides). *J FishtecH.* **5** 1 2016. Doi: https://doi.org/10.36706/fishtech.v5i1.3516.
27. B. O. Hemung, J. Yongsawatdigul, K. B. Chin, W. Limphirat, and Siritapetawee. Silver Carp Bone Powder as Natural Calcium for Fish Sausage. *J Aquat Food Prod Technol*. **27** 3 2018. Doi: 10.1080/10498850.2018.1432733.
28. Saadah, A. B. Tawali, M. Mahendradatta, Budimawan, Suryani, and F. Bastian. Increasing fishery added value through - The "Otak-Otak" development of mackerel fish. *World Appl Sci J*. **30** 30 2014.
29. M. Oppong Siaw, Y. J. Wang, A. M. McClung, and A. Mauromoustakos. Effect of protein denaturation and lipid removal on rice physicochemical properties. *LWT*. **150** 2021. Doi: 10.1016/j.lwt.2021.112015.
30. J. Wang, A. Li, J. Hu, B. Zhang, J. Liu, Y. Zhang, and S. Wang. Effect of Frying Process on Nutritional Property, Physicochemical Quality, and in vitro Digestibility of Commercial Instant Noodles. *Front Nutr*. **9** 2022. Doi: 10.3389/fnut.2022.823432. PMID: 35252303; PMCID: PMC8891372.
31. K. I. Jeyasanta, and J. Patterson. Nutritive Evaluation of Trash Fishes in Tuticorin (India). *World J Fish Mar Sci.* **6** 3 2014.
32. B. Triyono, S. Handoyo, and N. Laili. Analysis for Development of Mocaf-Based Functional Food Industry in Indonesia. *J Socioecon Dev*. **2** 2 2019. Doi:

10.31328/jsed.v2i2.1068.
33. B. R. Hamaker, Y. E. Tuncil, and X. Shen. Carbohydrates of the Kernel. *In: Corn: Chemistry and Technology, 3rd Edition.* 2018. Doi: 10.1016/B978-0-12-811971-6.00011-5.
34. K. Huber, and J. BeMiller. Carbohydrate Analysis. In Nielsen. *Cham: Springer International Publishing.* 303-329 2024. Doi: https://doi.org/10.1007/978-3-319-45776-5_19.
35. T. Wu, M. Wang, P. Wang, H. Tian, and P. Zhan. Advances in the Formation and Control Methods of Undesirable Flavors in Fish. *Foods*. **11** 2022. Doi: https://doi.org/10.3390/foods11162504.
36. S. Saxena. A review study on important role of carbohydrates in the flavor. *Asian J Res Soc Sci Humanit.* **11** 12 2021. Doi: 10.5958/2249-7315.2021.00324.5.
37. A, Riansyah, A. Supriadi, dan R. Nopianti. PENGARUH PERBEDAAN SUHU DAN WAKTU PENGERINGAN TERHADAP KARAKTERISTIK IKAN ASIN SEPAT SIAM (Trichogaster pectoralis) DENGAN MENGGUNAKAN OVEN. *J FishtecH*. **2** 1 2014. Doi: https://doi.org/10.36706/fishtech.v2i1.1103.
38. Y. Gao, M. E. Janes, B. Chaiya, M. A. Brennan, C. S. Brennan, and W. Prinyawiwatkul. Gluten-free bakery and pasta products: prevalence and quality improvement. *International Journal of Food Science and Technology*. **53** 2018.
39. L. de Oliveira, L. C. de Orlandin, L. A. de Aguiar, V. A. V. Queiroz, R. P. Zandonadi, Botelho, et al. Gluten-Free Sorghum Pasta: Composition and Sensory Evaluation with Different Sorghum Hybrids. *Foods*. **11** 19 2022. Doi: https://doi.org/10.3390/foods11193124.